Simultaneous measurements of transient photo-current and photoluminescence for $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P/Al_xIn_{1-x}P$-superlattices

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Carrier dynamics in semiconductors have been studied by time resolved photoluminescence measurements (TRPL). It is known that indirect transition type semiconductors have the photoluminescence (PL) life time of microseconds or longer. However, the effect of the carrier diffusion or transport is not yet investigated. Transient photo-current measurement called time of flight (TOF) is reported to give us the transit time of photo-generated carries to the conductive substrate or a electrode. However there is no report on the simultaneous measurements of TRPL and TOF. Recently AlGaInP crystals are applied to the solar cells. The superlattices (SLs) such as $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P/Al_xIn_{1-x}P$ have the preferable properties of the indirect transition type, which leads to the smaller radiative loss of carriers, and wider controllable energy gap range by the introduction of the strained layers.

Undoped disordered $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ (1.0μm) and $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$(20nm)/$Al_xIn_{1-x}P$ (8nm)-SLs (20 cycles) were grown on n-GaAs (1-3×$10^{18}$$cm^{-3}$) substrates by a metal organic vapor phase epitaxy system. The band energy diagram of the SL with x=0.53 is drawn in Fig.1. The samples with and without electrodes were studied by TRPL measurements. The samples were excited by the 337nm line of a nitrogen laser. The PL was detected by a streak scope system or a photomultiplier - 500 MHz digital oscilloscope system. In TOF measurements, the samples were excited by the nitrogen laser. The photo-current was detected by the oscilloscope.

Examples of the TOF measurements for the SL sample with x=0.53 are shown in Fig. 2(a). As the bias voltage (V_b) applied on the semitransparent Au electrode on the SLs decreases from 0 V, the maximum current increases. The PL intensities at 541 nm simultaneously obtained with the photo-current are shown in Fig.2(b). The temporal development of the sample without the electrodes is similar to that with the bias voltage of –0.1 - –0.01 V. It is concluded that the time dependence of the PL intensity without electrode is determined by the recombination of the carriers localized in the X_c level of one or two $Al_{0.53}In_{0.47}P$ layers. Figure 3(a) shows the TRPL integrated over the whole energy band observed by the streak scope for the sample without electrodes. Figure 3(b) shows the transient photo-current in the incipient time range. The PL intensity in the time range of 0 – 150 ns is estimated to be affected by the transport of the carriers overflowed to the $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ X_c level.

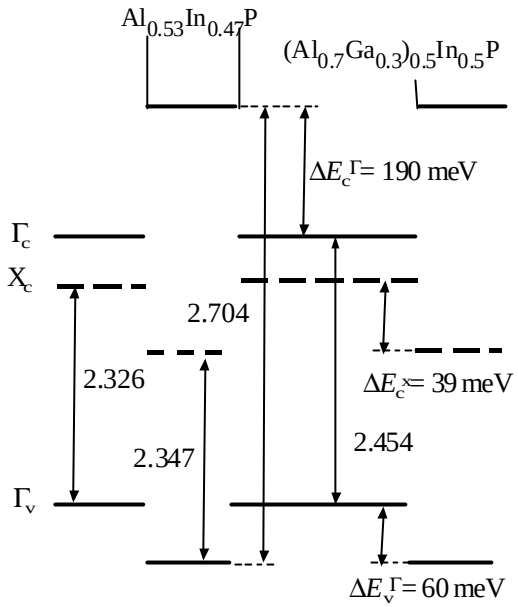

Fig. 1 Band energy diagram of the $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P/Al_{0.53}In_{0.47}P$-SL at 10 - 20 K.

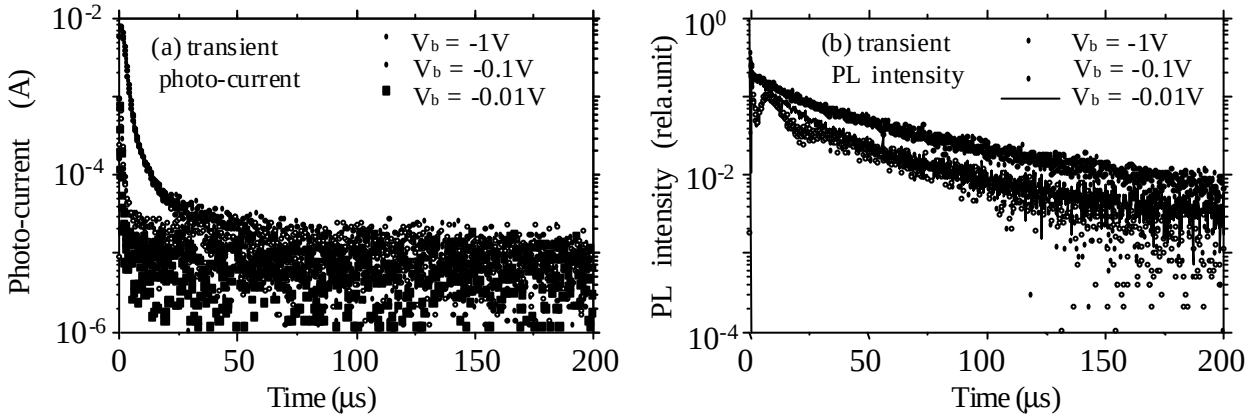

Fig. 2 Bias voltage dependence of transient photo-current and PL intensity at 7 K. The PL is obtained at 541 nm.

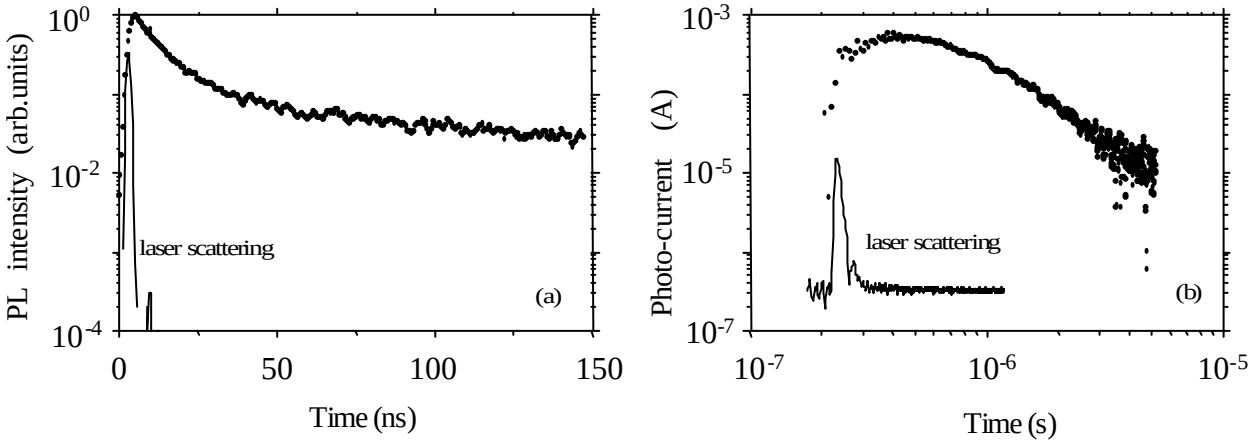

Fig. 3 Time response in the incipient time range.
(a): TRPL for the sample without Au electrode. (b): TOF with V_b of -0.01 V